INFLUENCE OF WALL ROUGHNESS ON WIND PRESSURE DISTRIBUTION AND VENTILATION LOSSES

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1. ABSTRACT

This paper describes a wind tunnel investigation of wind pressure distribution over a 1:100 scale model of a 12-storey block-type building in open country exposure. Appurtenances attached to one wall of the building included: vertical mullions with different height and spacing, combination of vertical and horizontal mullions and three types of balconies.

Pressure coefficients obtained from the tests were used for the calculation of air exchange rates and associated heat losses from a hypothetical naturally ventilated room or flat situated in various locations in the building. The results are presented in a non-dimensional coefficient of ventilation loss reduction, r_Q, which relates the resulting change in ventilation loss caused by wall roughness, ΔQ, to ventilation loss from the room or flat, when the building walls are smooth, Q_s.

2. INTRODUCTION

The prediction of wind loads and associated ventilation losses of a building is generally difficult and it becomes even more complex when architectural features are present. Their functional purpose was mostly explained by sunshine protection. But the roughness of the wall modify the flow regime near the surface which can influence also the air infiltration process, the heat convection, the driven rainfall distribution etc.

The pressure coefficients that are given in building codes are primarily intended for wind loading applications and the values quated are the maximum values for particular facade. Adaptation of these pressure coefficients for air infiltration models is not suitable, because where the pressure distribution is non-uniform, the extreme values can differ from the mean value for the facade as much as 50 % (1). However, when the building has different kinds of appurtenances the application of these provisions becomes doubtful.

The literature survey indicated that the wind pressure data amount which is available is still very small in relation to the wide range of building shapes and their appurtenances which are of common interest. Only a limited number of experimental studies in this field has been made. For instance, Leutheusser (2) reported the effect of mullions and the authors in (3) discussed the effect of balconies and uniform roughness.

The purpose of the present wind tunnel study is to provide wind pressure data for a rectangular high-rise building equipped with various types of mullions and balconies. The wind pressures obtained in the tests have been used as input data in an analytical model for the calculation of air change rates and corresponding heat losses for a hypothetical room or flat in building as influenced by the facade roughnesess investigated.

A full report of the investigation will be given in (4).

3. EXPERIMENTAL WORK

All measurements in this study were made in the boundary layer wind tunnel located in the Aerodynamics Laboratory of the National Swedish Institute for Building Research. This tunnel is of the closed-circuit type with a test section 3 m wide, 1.5 m high and 11 m long.

An atmospheric boundary layer over rural terrain was simulated by means of spires at the upstream end of the test section and 7 m fetch of 40 mm cubes in a regular array with a density of 10 %. The model boundary layer had a height of 1.0 m and a mean velocity profile given by $u \doteq z^{0.16}$.

The 1:100 scale building model was made of wood with dimensions as shown in Fig. 1. The model was equipped with pressure taps at the centres of all the supposed windows and doors at three different levels.

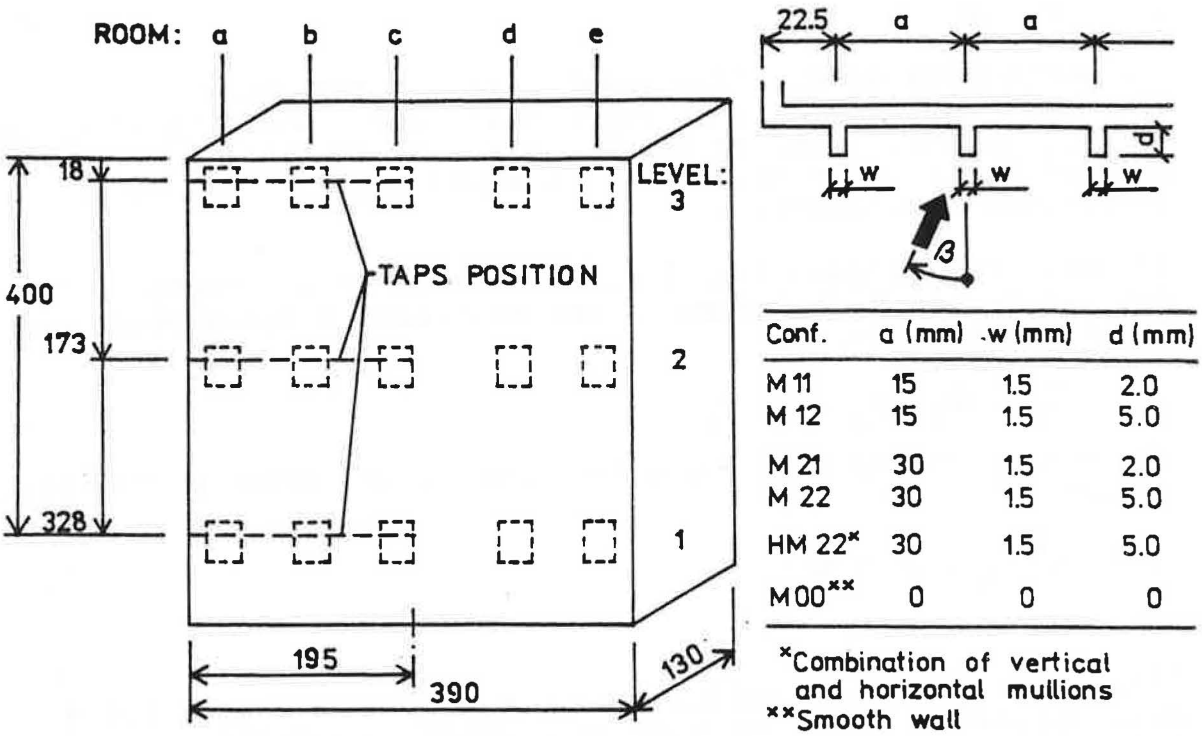
Two types of appurtenances were considered in the experiments. In the first series of tests, the influence of mullions with various height and spacing was studied, as indicated in Fig. 1. In the second test series, the frontal wall was equipped with various types of balconies, which are shown in Fig. 2.

In all test series the wind angle was varied between 0° and 330° in increments of 30°.

4. CALCULATION MODEL

Wind pressure coefficients obtained from the wind tunnel tests have been used for calculation of air change rates and associated heat losses for a full scale house as they might be influenced by appurtenances and climatic conditions (wind speed and air temperature).

The air infiltration rate through a leakage opening for steady-state conditions can be expressed by



Conf.	a (mm)	w (mm)	d (mm)
M 11	15	1.5	2.0
M 12	15	1.5	5.0
M 21	30	1.5	2.0
M 22	30	1.5	5.0
HM 22*	30	1.5	5.0
M 00**	0	0	0

*Combination of vertical and horizontal mullions
**Smooth wall

FIGURE 1. Model dimensions. Location and dimensions of wall mullions.

$$I = A_1/h \int_0^h (\rho(\Delta p_W + \Delta p_T)/2)^{0.5}\, dz \qquad (1)$$

and the corresponding heat loss is given by

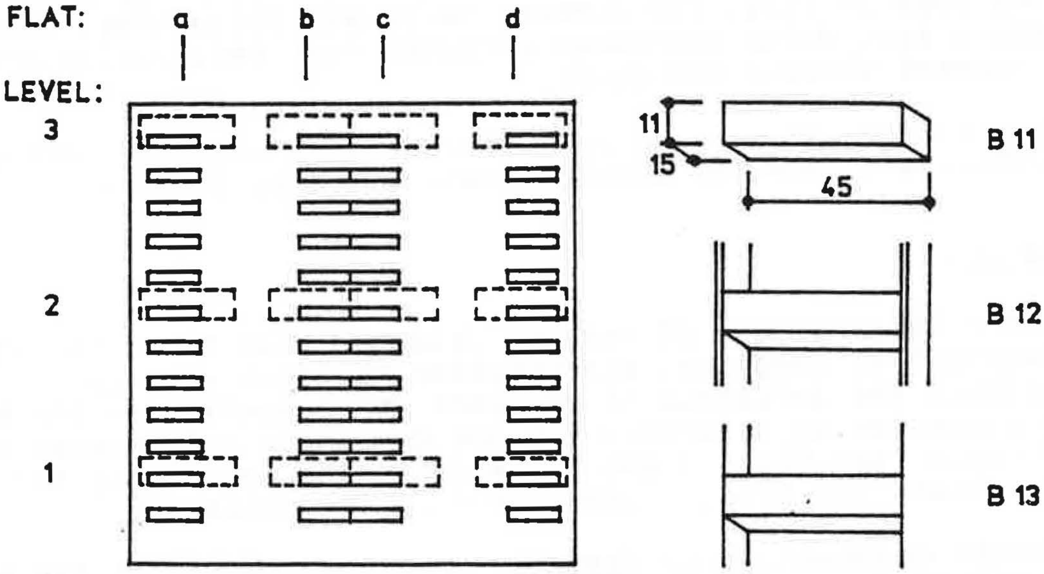


FIGURE 2. Location and dimensions of balconies.

$$Q = I \rho c \Delta T \qquad (2)$$

The analytical calculation model used for the calculation is based on Eq. (1). It is a single-cell model, which is discribed in (4). In this model we propose that any vertical connection between floors does not exist, it means the building is of story-type construction.

To prove the influence of facade elements of air change rates and associated heat losses it was developed a non-dimensional reduction coefficient

$$r_Q = (Q_s - Q_r)/Q_s = \Delta Q/Q_s \qquad (3)$$

The heat loss reduction is a function of the densimetric Froude number

$$Fr = (u^2 T_e)/(g h \Delta T) \qquad (4)$$

as shown in (5).

Flow calculation for mullions configuration were made for a hypothetical office room with no internal divisions and both exterior walls have the same leakage area and are equipped with mullions. The limited exterior wall area of office room is expressed in Fig. 1, in dimensions 3.0 m wide and 2.8 m high.

Flow calculation for balconies configuration suppose a hypothetical flat with no internal divisions. The exterior walls of the flat have the same leakage area and one of them is equipped with balcony. The limited exterior wall area of the flat is expressed in Fig. 2, in dimensions 7.5 m wide and 2.8 m high.

The calculation of ventilation losses is based on one average value of wind pressure coefficient for each of envelope walls of the room or flat. The average value was calculated from pressure taps which represent averages over rectengular areas of supposed windows and doors.

From all calculations the situation of wind angle $\beta = 90°$ was excluded, when the infiltration rate is equal to zero.

5. RESULTS

From the large amount of results obtained from the calculations a selection of graphical presentation has been made to illustrate the influence of mullions and balconies on the heat loss reduction as a function of the densimetric Fr-number and wind angle (see Figs. 3 and 4). Whereas the results of all calculations are briefly summarized in the following.

A general observation is that the greatest changes of the heat loss reduction coefficient, r_Q, are in the range of Fr-number $0 < Fr < 10$, where the r_Q-value reached also it´s maximum.

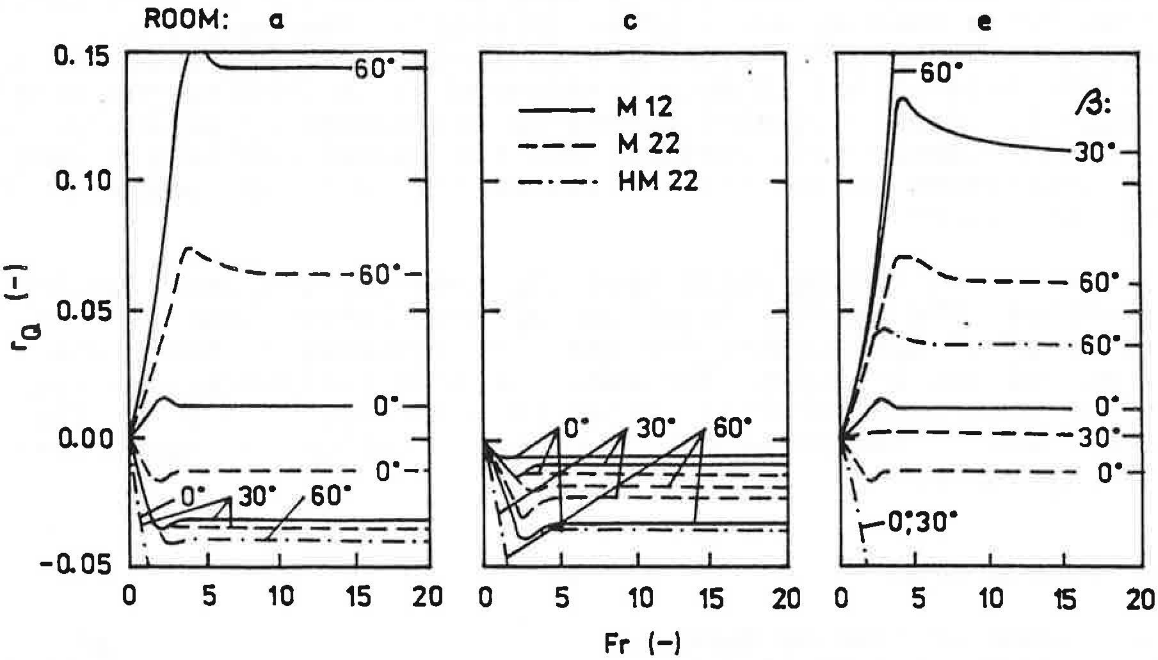


FIGURE 3. Reduction of ventilation loss, r_Q, versus Fr-number for rooms on 3rd level. Building with mullions, wind angles β = 0,30 and 60°.

At Fr > 15 are the r_Q-values nearly constant.

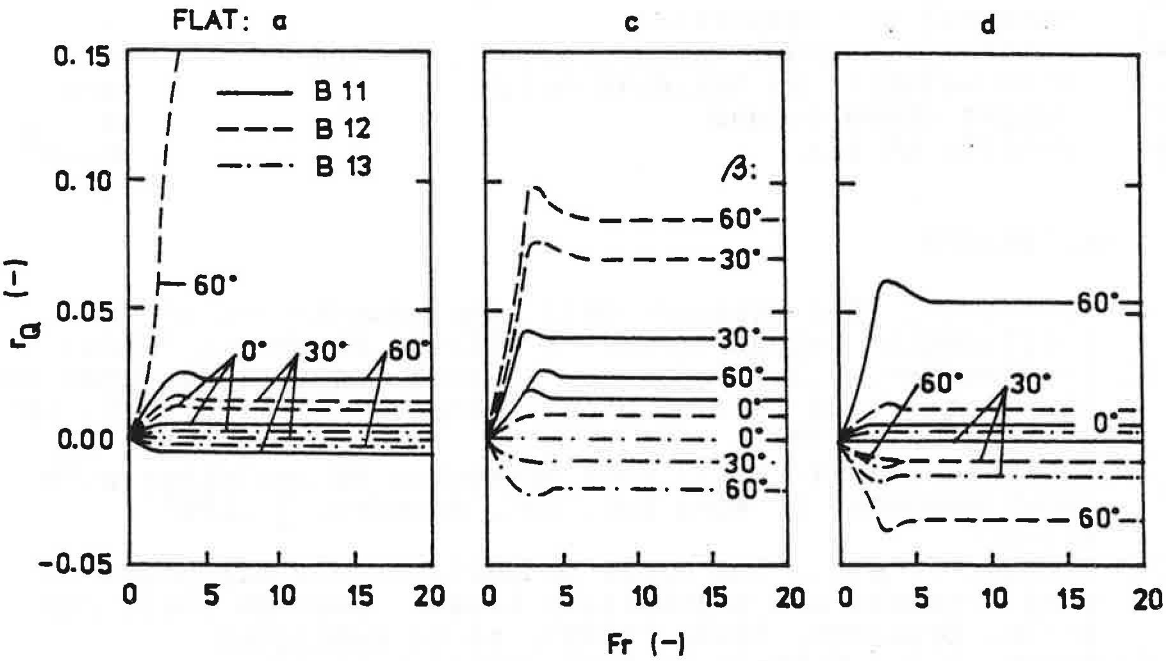


FIGURE 4. Reduction of ventilation loss, r_Q, versus Fr-number for flats on 3rd level. Building with balconies, wind angles β = 0,30 and 60°.

Mullion configurations give a maximal reduction of ventilation loss for a room by about 20 %. Increasing the height of mullions and adding horizontal mullions increases also the r_Q-value. This effect is more pronounced by increasing the wind angle for rooms situated closed to the corner of building. But also the facade with vertical and horizontal mullions causes an increasing of ventilation losses (c. 10 %) obviously on the highest floor.

Balconies with side walls have the greatest influence on the r_Q-value. The maximal reduction of ventilation loss is about 20 %, which was reached for the flat situated on the highest floor of the building. The other balcony configurations cause reduction of ventilation losses in the range of ± 10 %. The balconies on the leeward side does not influence significantly the r_Q-value.

6. NOMENCLATURE

A_l	area of leakage openings	m^2
c	specific heat of air	kJ/kgK
Fr	Froude number	-
g	acceleration of gravity	m/s^2
h	height of storey	m
I	air infiltration rate	m^3/s
Δp_W	wind pressure difference	Pa
Δp_T	thermal pressure difference	Pa
Q	ventilative heat loss (index: s = smooth wall, r = rough wall)	kWh/day
ΔQ	reduction of heat loss	kWh/day
r_Q	heat loss reduction factor	-
Te	external air temperature	K
ΔT	external-internal temperature difference	K
u	wind velocity at building height	m/s
z	height above ground	m
ρ	density of air	kg/m^3

7. REFERENCES

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